Mr. Shelby Williams
NEVADA POWER COMPANY
P.O. Box 77
Moapa, Nevada 89025

Subject: Cooling Tower Fan: Vibration Analysis and Mechanical Inspection.
Nevada Power Company Purchase Order No. 28462
MEZCO Corporation Project No. Z85-010

Dear Mr. Williams:

Enclosed please find two copies of our report entitled, "COOLING TOWER FAN: VIBRATION ANALYSIS AND MECHANICAL INSPECTION." Data for this report was acquired between the periods of April 7, 1985 and April 15, 1985. Please feel free to contact us regarding any questions you may have on this report.

At this time we would like to acknowledge the excellent cooperation and assistance rendered by your staff.

Sincerely yours:

Claude H Kouchi

Claude H. Kouchi
MEZCO CORPORATION
7721 Colgate Avenue
Westminster, CA. 92683
(714) 894-6017

cc: Mr. William E. Theisen
Mr. David R. Webster

"COOLING TOWER FAN"
"VIBRATION ANALYSIS AND MECHANICAL INSPECTION"

Prepared for:

NEVADA POWER COMPANY

Reid Gardner Station

Moapa, Nevada

Prepared by:

Claude H. Kouchi

and

Lance T. Kouchi

MEZCO CORPORATION

Westminster, California

Data Acquisition Dates: April 7, and April 15, 1985

NEVADA POWER COMPANY Purchase Order No. 28462

MEZCO CORPORATION Project No. Z85-010

Report Date: April 22, 1985

TABLE OF CONTENTS

1.0 INTRODUCTION

The NEVADA POWER COMPANY, REID GARDNER UNIT NO. 4 at Moapa, Nevada, has experienced four cooling tower drive shaft failures. These cooling tower fans were commissioned for service in 1983 and have had mechanical problems with the main gearbox, center support bearings and motor bearings.

On January 30, 1985, the inboard drive shaft failed on the "B" cooling tower fan. Subsequently, similar failures have occurred on fans "A", "D" and "F".

NEVADA POWER COMPANY requested MEZCO Corporation to assist in the evaluation of the drive shaft failure and recommend a permanent solution to this problem.

Based on the mechanical inspection, vibration analysis and information furnished by NEVADA POWER COMPANY personnel, we have concluded that the primary suspected cause is improper coupling gaps due to thermal growth of the shafts. The limited float coupling design does not allow sufficient axial growth. This causes the shaft to bow in the center and causes additional axial stress on the bearings.

2.0 SUMMARY AND CONCLUSIONS

2.1 The primary suspected cause of the drive shaft failure is improper coupling gap between the Gearbox, Center support bearing and Motor. When the coupling is too close, the thermal growth of the shaft will cause the shaft to bow in the center. This bow will also trap water in the drive shaft and resulting is a shaft failure.

2.2 Center support and motor bearing failures can be attributed to excessive axial loading due to improper coupling gaps. This was evident by high center support bearing temperatures.

2.3 High gearmesh vibration frequencies (28,800 cpm) in the gearbox suggest that the input gear to the intermediate gear has improper gearmeshing. We suspect this is caused by defective bearings which is the result of excessive axial bearing loads.

2.4 Water accumulation in the drive shafts could result in shaft failure due to unbalance.

3.0 RECOMMENDATION

3.1 Perform a mechanical inspection on all the fans for proper coupling gaps and alignment. Assemble coupling with .040 to .060 inches for thermal growth.

3.2 Evaluate alternate coupling designs which would allow greater axial growth. MEZCO will furnish a recommendation at a later date.

3.3 Install a sun shield over the drive shaft to reduce the thermal effects when the fans are not running. So Cal Edison, Etiwanda station, found that the sun was bowing the shafts when the fans were not running.

3.4 Install water drain holes in the drive shafts if water still accumulates inside the shaft. Install holes recommended by Marley Company.

3.5 Install proper length keys in coupling hubs. This will reduce vibration caused by unbalanced coupling components.

3.6 Install vibration transducers and monitors on the center support bearings. This will provide the necessary vibration information needed to predict future bearing failures.

3.7 Install an auxiliary or internal oil pump in the gearbox. This will provide additional cooling to the bearings and gears during the summer months. The splash lubrication system was found inadequate to provide lubrication to upper bearings and gears when the fan is free wheeling.

3.8 The Bently Nevada vibration monitor alarm point for the "B" path should be lowered from 5 mils to 3 mils and the danger point should be lowered from 10 mils to 5 mils. Originally, the higher vibration alarm levels were selected for a wood constructed cooling tower. Since your cooling towers are constructed of concrete, lower alarm points should be used due to the fact that concrete limits overall movement.

4.0 DISCUSSION OF RESULTS

4.1 DRIVE SHAFT NATURAL RESONANCE TEST — Plot no. 1

Both drive shafts were tested for their natural resonances by exciting the shaft with a rubber mallet.

The 5 inch drive shaft natural resonance = 2760 cpm
The 4 inch drive shaft natural resonance = 3960 cpm

Both of the shaft's natural resonances are well above the running speed of the motor.

4.2 COOLING TOWER FAN: CELL "D" — Plot no. 2

Cell "D's" drive shaft was aligned within the acceptable limits, however, no movement between the center support bearing and the No. 2 drive shaft was made since the center support bearing housing was bolt bound and thus prevented us from making any moves.

The gearbox spectrum shows an input shaft gearmesh frequency of 0.27 inch per second at 28,800 cpm. This indicates that the bearing on the input shaft has excessive wear and should be replaced and readjusted for proper gearmesh and backlash. Please monitor the vibration level closely and perform a mechanical inspection when the vibration level reaches 0.3 inch per second.

4.3 COOLING TOWER FAN: CELL "A" — Plot no. 5

Cell "A's" gearbox vibration level is considered in the ALARM level. The gearbox should be inspected for bearing condition and proper gearmesh. We found that the drive-shaft coupling gaps were too wide on both drive-shafts. The center support bearing housing temperature was very hot, suggesting that the bearing was subjected to high axial forces.

4.4 COOLING TOWER FANS: CELLS "B, C, and E" — Plots no. 5 & 6

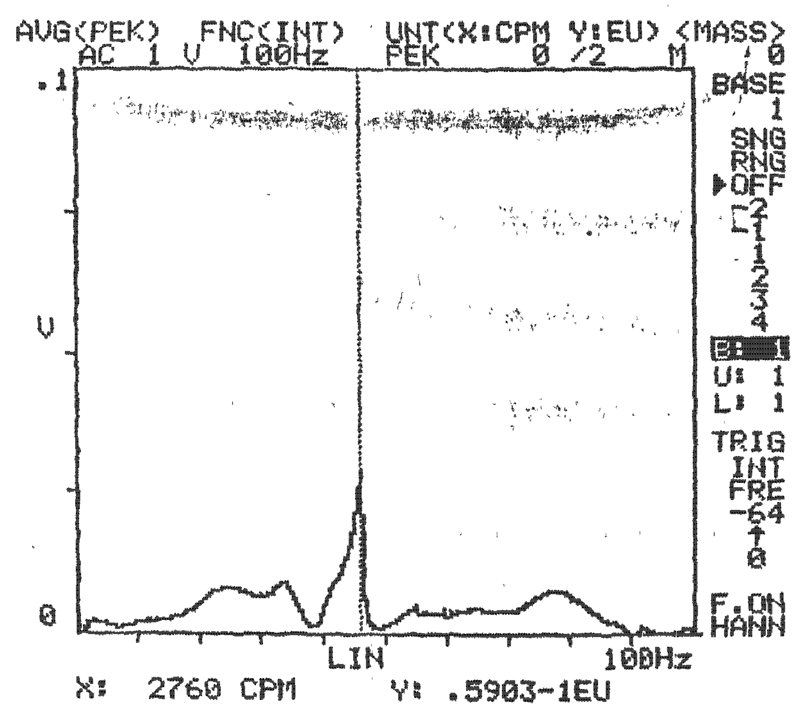
The spectrum plots for these gearboxes suggests that these units are running within acceptable vibration levels.

4.5 COOLING TOWER FAN: CELL "G" Plots no. 11 & 12

Cell "G's" gearbox vibration levels are considered to be in the ALARM level. The gearbox should be inspected for bearing condition and proper gearmesh. We found that the drive-shaft coupling gaps were too narrow on both shafts. The narrow coupling gaps would cause the drive-shaft to be in constant compression, especially with the thermal growth and thus cause the drive shafts to bow in the center.

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 1

NUMBER ________ MACHINERY COOLING TOWER DRIVE SHAFT



Date: APRIL 8, 1985

Time: 08:58

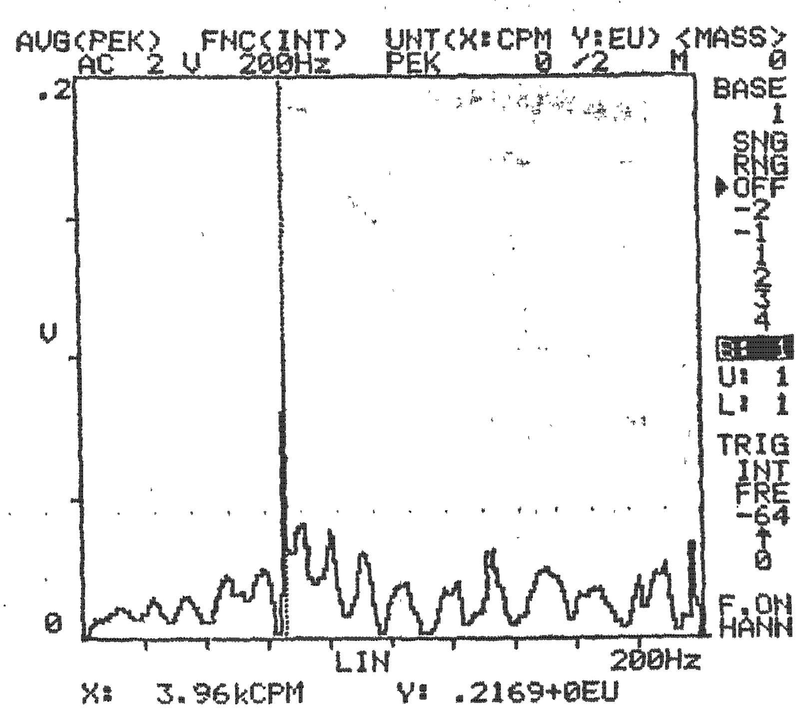
Machine: 1st shaft

Loc: ____________

I.P.S. .059

Mils _____ Deg _____

Remarks: NATURAL RESONANCE OF SHAFT 2760 cpm



Date: APRIL 8, 1985

Time: 09:15

Machine: 2nd shaft

Loc: ____________

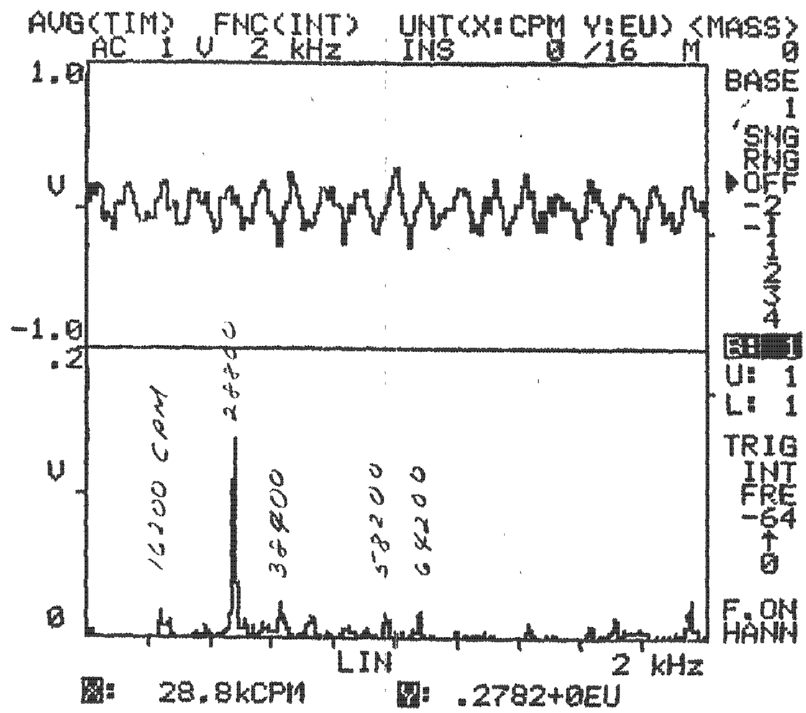
I.P.S. .21

Mils _____ Deg _____

Remarks: NATURAL RESONANCE OF SHAFT 3960 cpm

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 2

NUMBER NO. 4D MACHINERY COOLING TOWER FAN



Date: APRIL 19, 1985

Time: 03:37

Machine: 4D FAN

Loc: GEARBOX

I.P.S. ..278

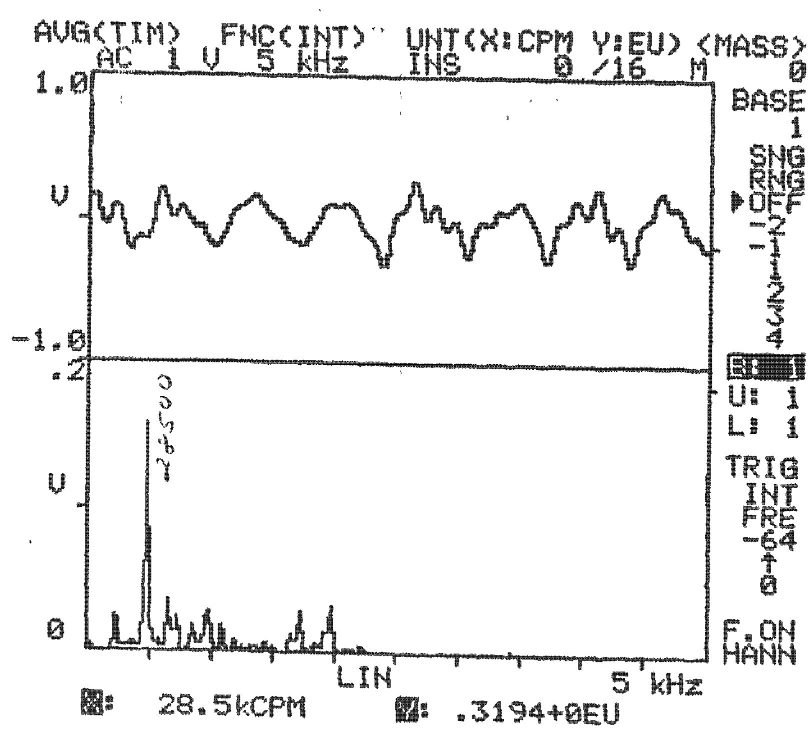
Mils ____ Deg ____

Remarks:

Installed new drive shaft and couplings.

Aligned Motor, Center support bearing.

Vib. suggest bad bearing or loose bear-input shaft bearing.



Date: APRIL , 1985

Time: 03:39

Machine: 4D FAN

Loc: GEARBOX

I.P.S.

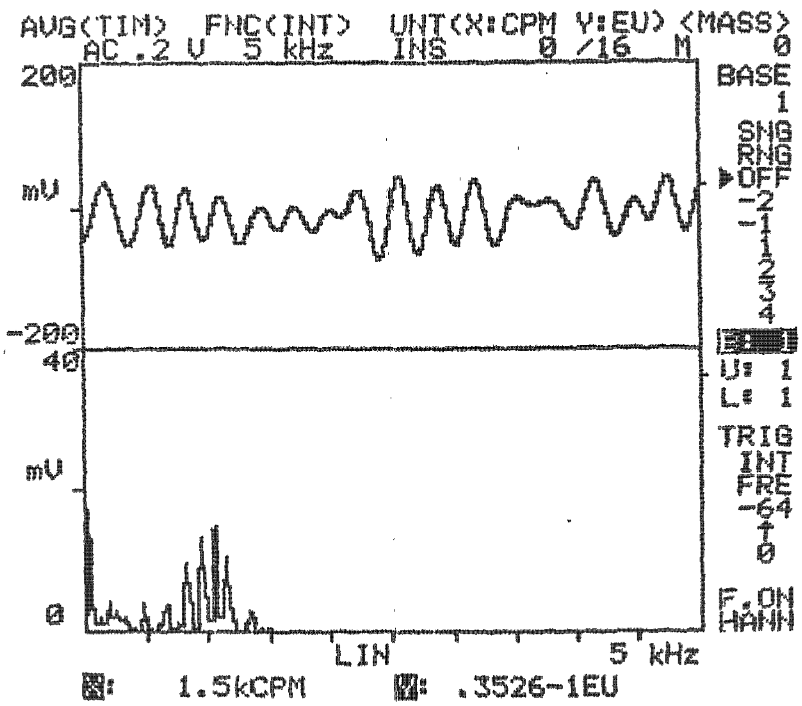
Mils ____ Deg ____

Remarks:

Same vib. point at 5 kHZ.

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 3

NUMBER 4 A MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

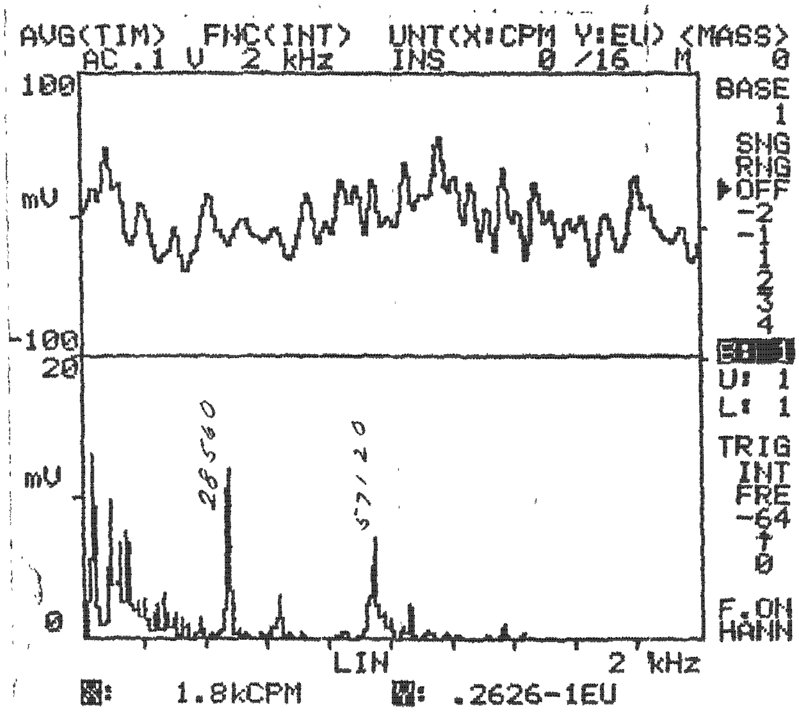
Machine: CENTER BRG.

Loc: HORIZONTAL

I.P.S. .035

Mils ____ Deg ____

Remarks: ____



Date: APRIL 8, 1985

Time: 23.20

Machine: CENTER BRG.

Loc: HORIZONTAL

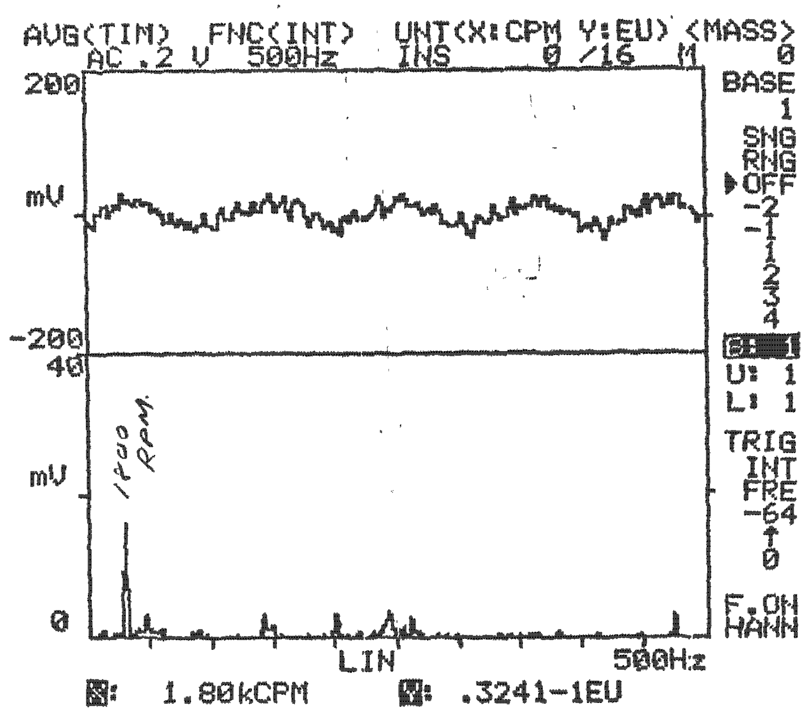
I.P.S. .026

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 4

NUMBER 4 A MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

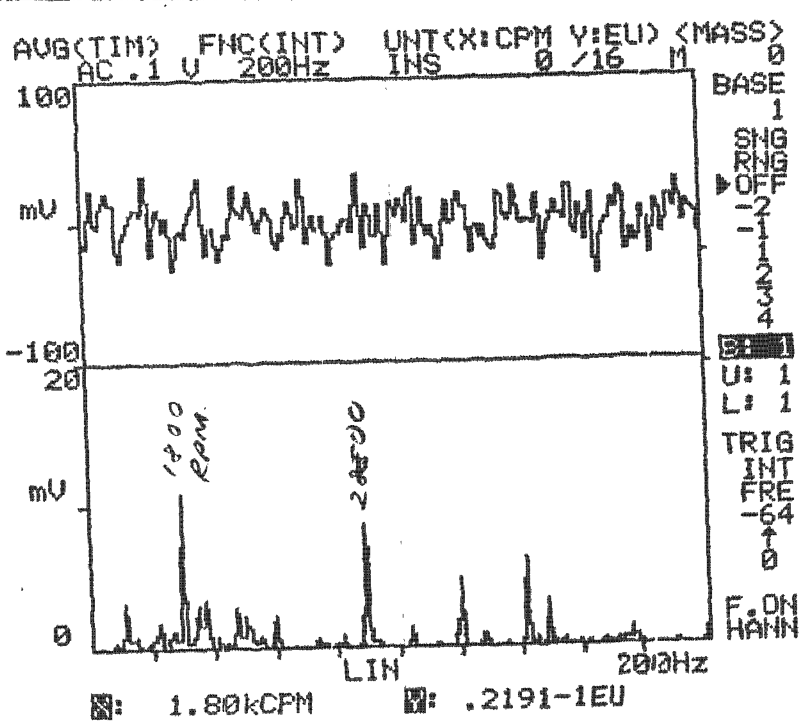
Machine: CENTER BRG.

Loc: HORIZONTAL

I.P.S. .03

Mils ____ Deg ____

Remarks: ____



Date: APRIL 8, 1985

Time: 23.20

Machine: CENTER BRG.

Loc: HORIZONTAL

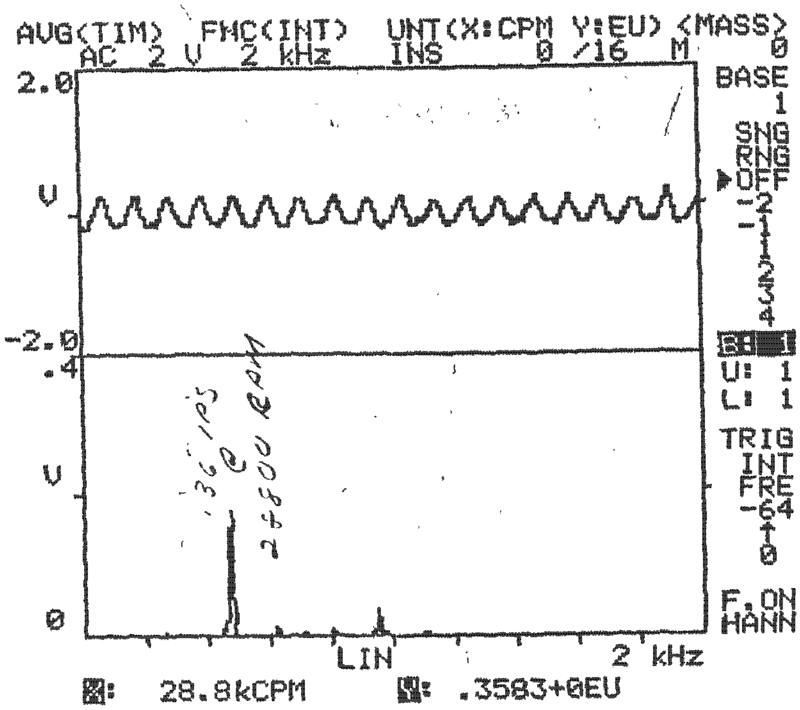
I.P.S. .02

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 5

NUMBER NO. 4 MACHINERY COOLING TOWER FAN



Date: APRIL 8, 1985

Time: 0927

Machine: 4A FAN

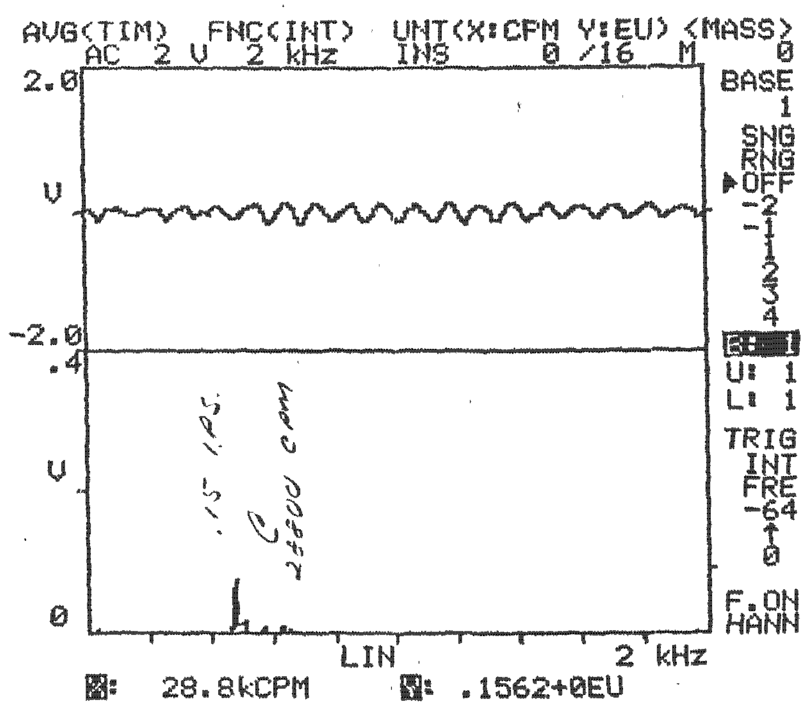
Loc: GEARBOX

I.P.S. .3583

Mils ____ Deg ____

Remarks:

Vibration levels are high. Should inspect Gearbox.



Date: APRIL 8, 1985

Time: 0930

Machine: 4B FAN

Loc: GEARBOX

I.P.S. .1562

Mils ____ Deg ____

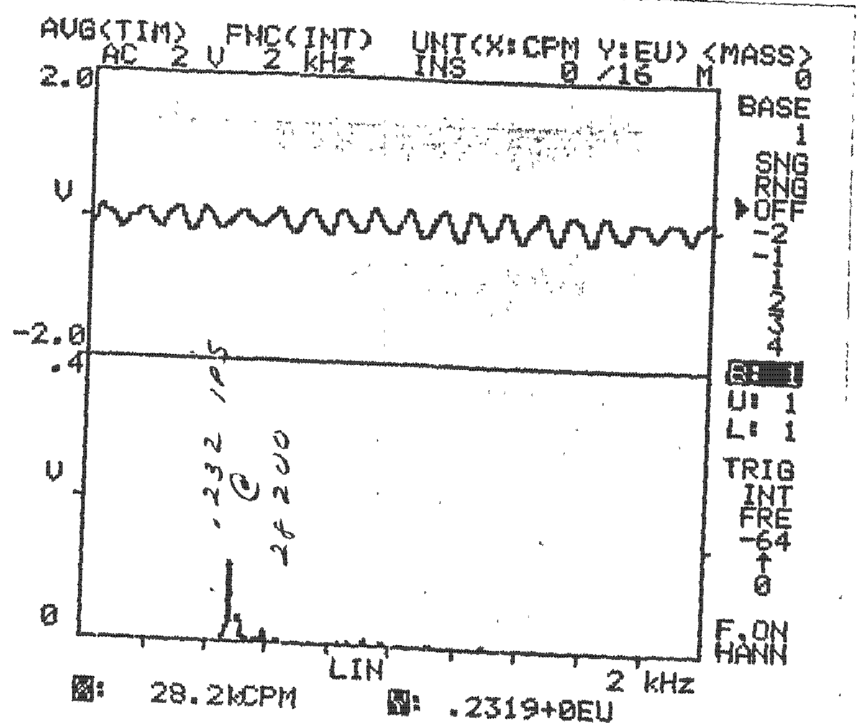
Remarks:

ACCEPTABLE VIB.

IP12_011490

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 6

NUMBER NO. 4 MACHINERY COOLING TOWER FANS



Date: APRIL 8, 1985

Time: 0940

Machine: 4C FAN

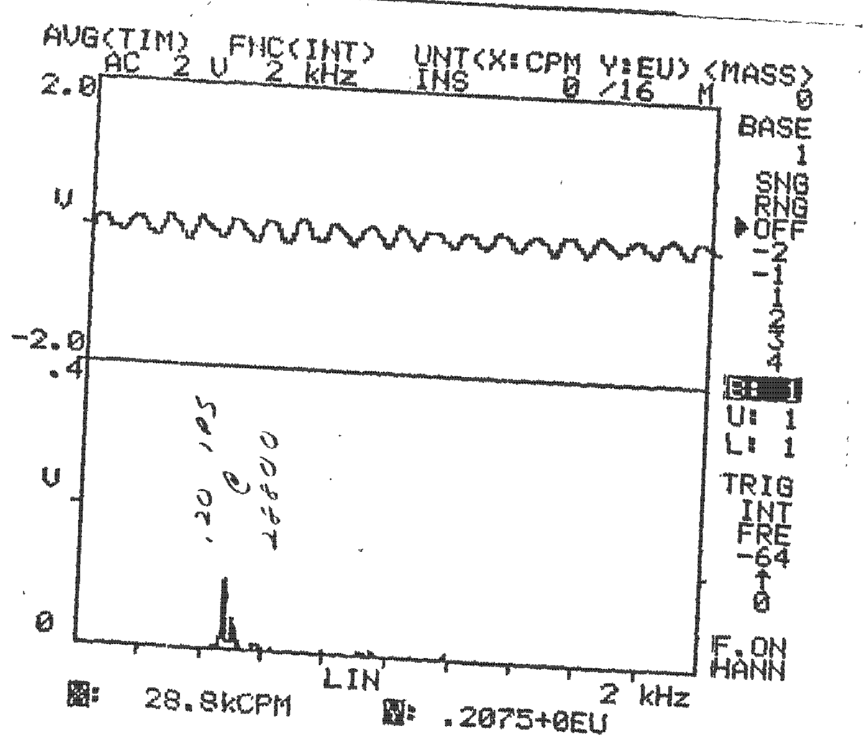
Loc: GEARBOX

I.P.S. .232

Mils ____ Deg ____

Remarks:

ACCEPTABLE VIB.



Date: APRIL 8, 1985

Time: 0950

Machine: 4E FAN

Loc: GEARBOX

I.P.S. .207

Mils ____ Deg ____

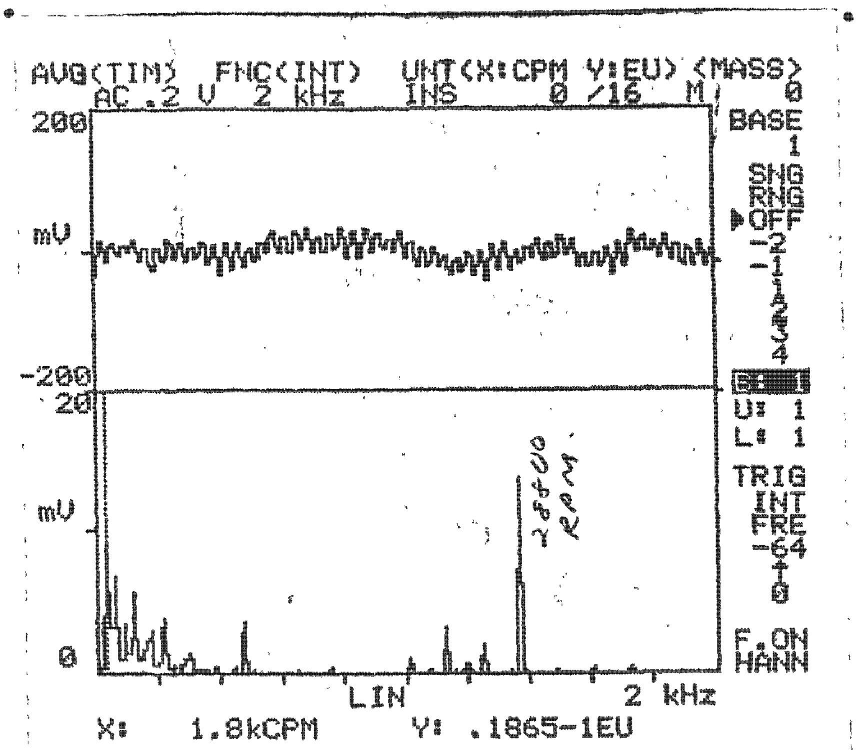
Remarks:

ACCEPTABLE VIB.

IP12_011491

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 7

NUMBER 4 G MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

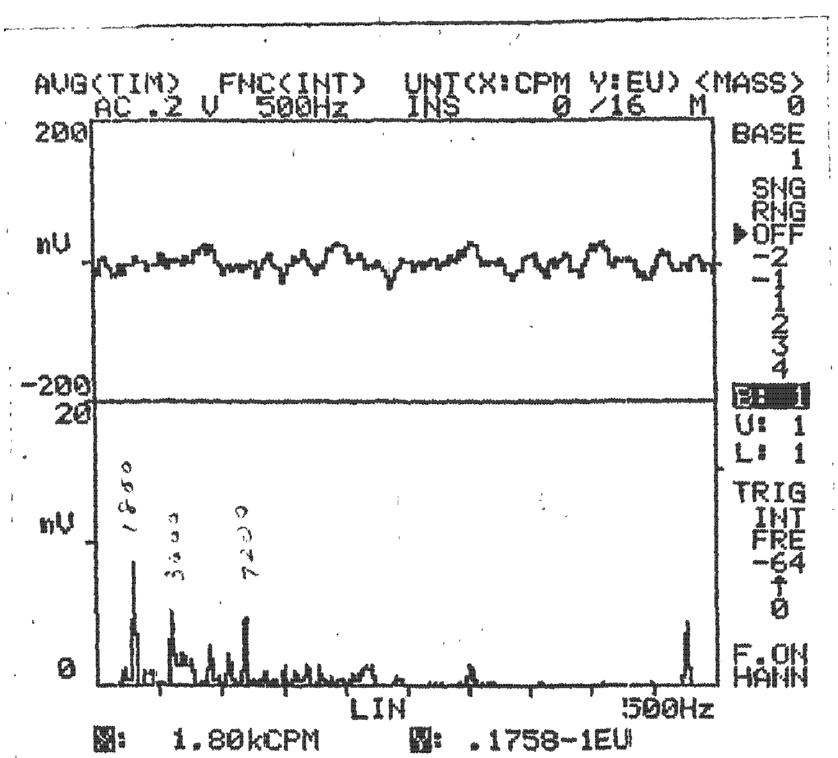
Machine: MOTOR

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks: ____



Date: APRIL 8, 1985

Time: 23.20

Machine: MOTOR

Loc: HORIZONTAL

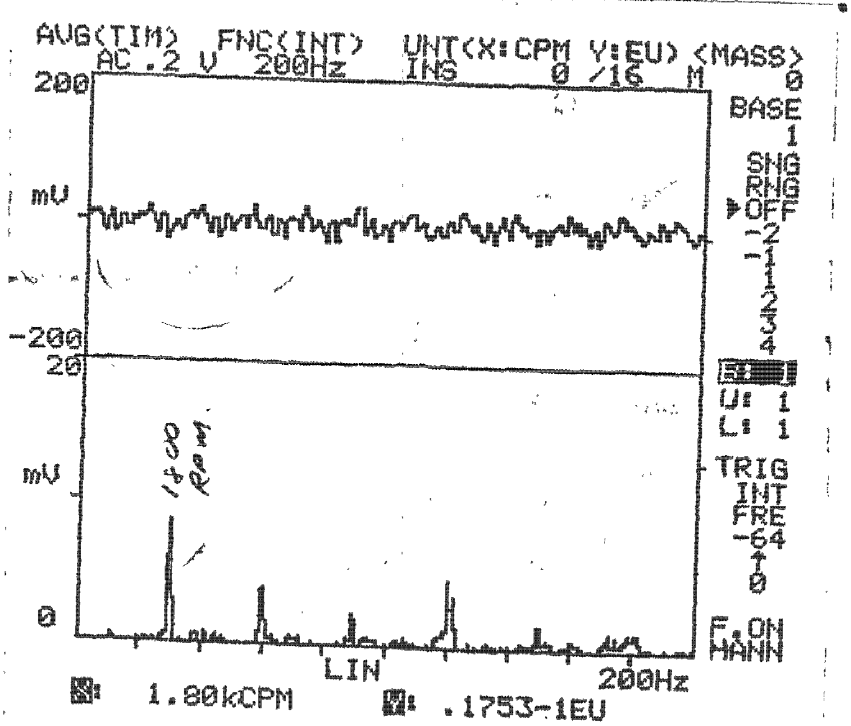
I.P.S.

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 8

NUMBER 4 G MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

Machine: MOTOR

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks: ____

Date: APRIL 8, 1985

Time: 23.20

Machine: MOTOR

Loc: HORIZONTAL

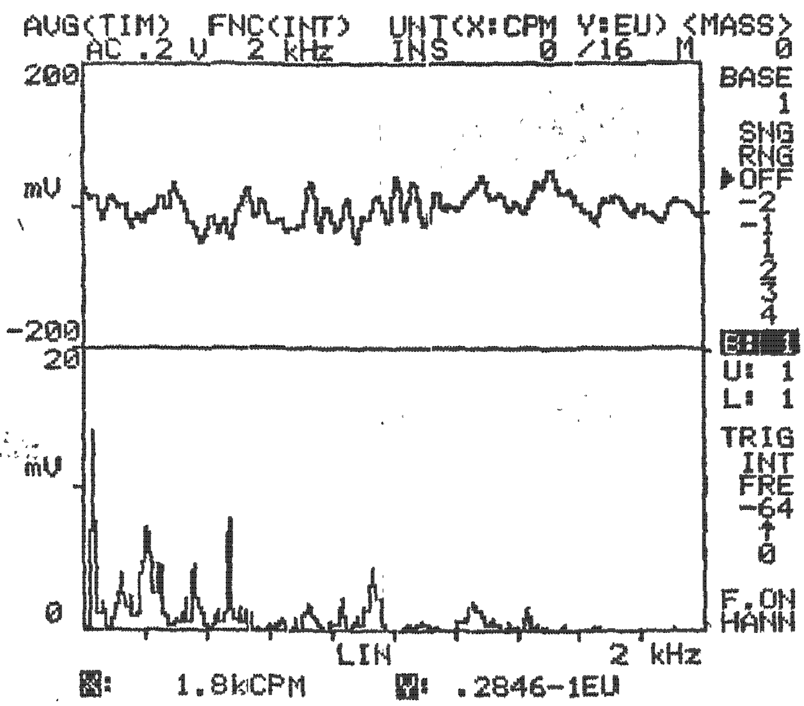
I.P.S.

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 9

NUMBER 4 G MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

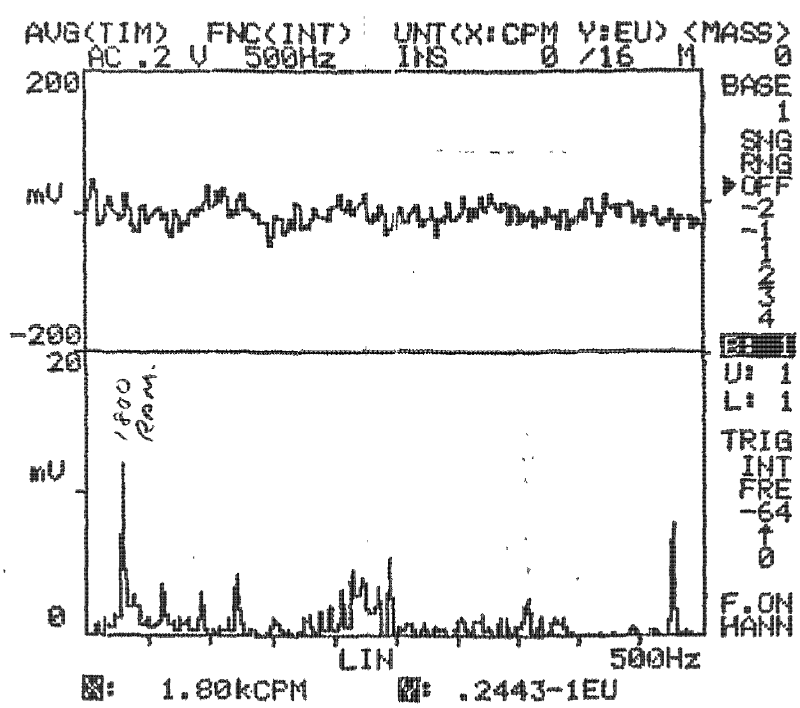
Machine: CENTER BRG.

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks: ____



Date: APRIL 8, 1985

Time: 23.20

Machine: CENTER BRG.

Loc: HORIZONTAL

I.P.S.

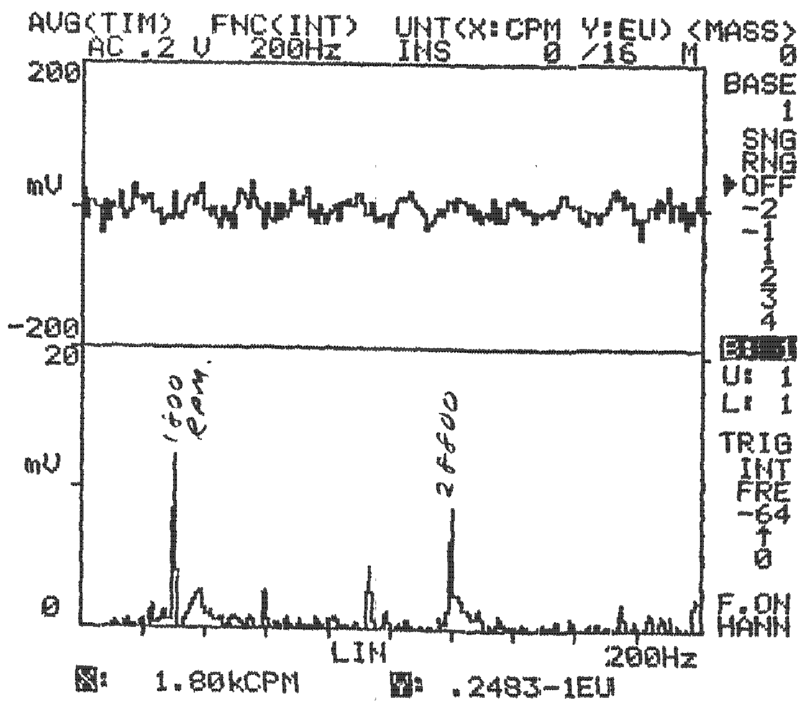
Mils ____ Deg ____

Remarks: ____

IP12_011494

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 10

NUMBER 4 G MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

Machine: CENTER BRG.

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks: ____

Date: APRIL 8, 1985

Time: 23.20

Machine: CENTER BRG.

Loc: HORIZONTAL

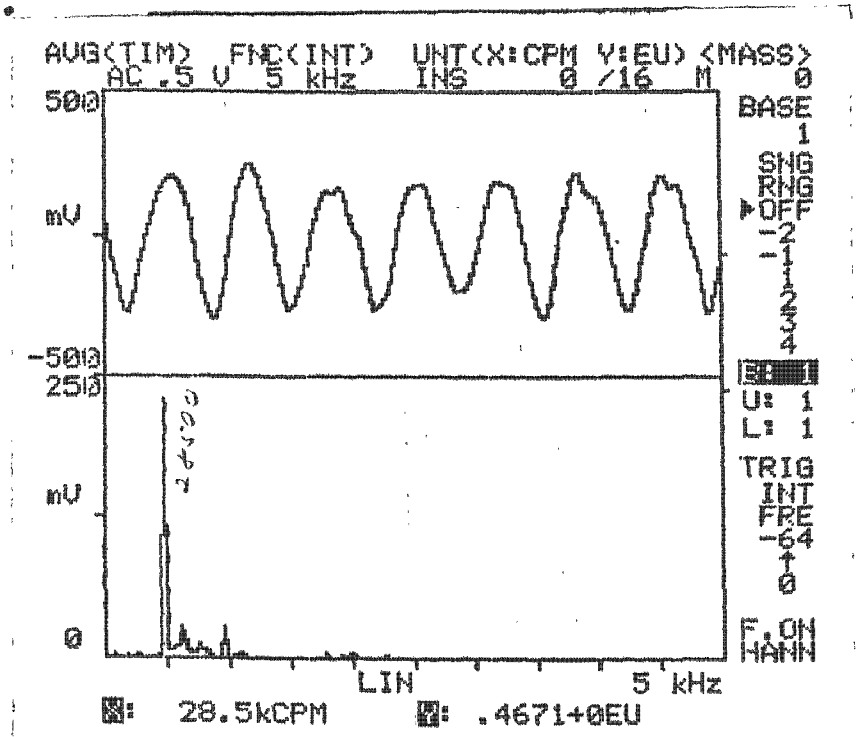
I.P.S.

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 11

NUMBER 4 6 MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

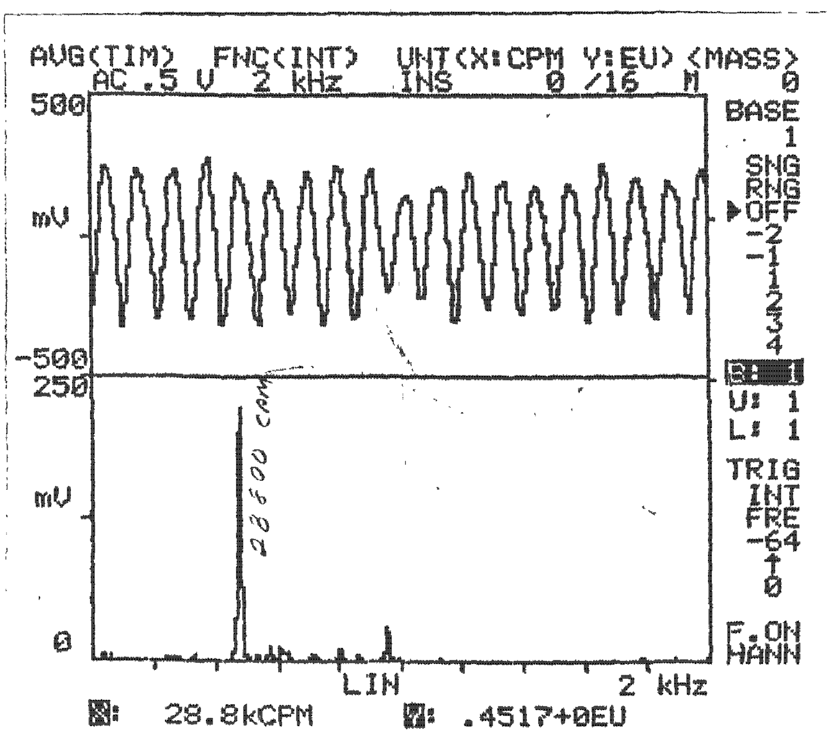
Machine: GEARBOX

Loc: HORIZONTAL

I.P.S. .4671

Mils ____ Deg ____

Remarks: ____



Date: APRIL 8, 1985

Time: 23.20

Machine: GEARBOX

Loc: HORIZONTAL

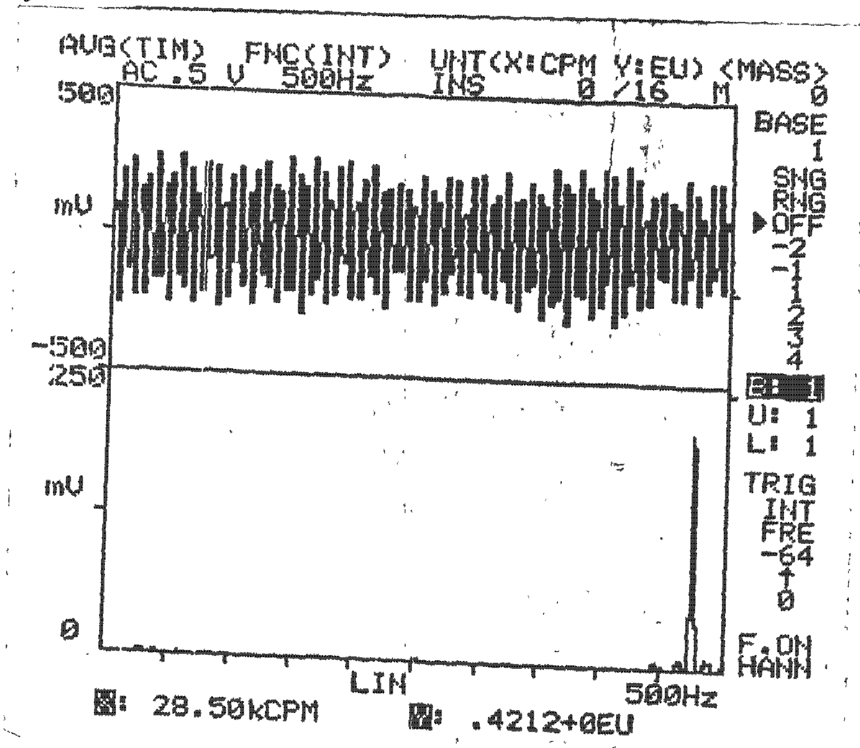
I.P.S. .4517

Mils ____ Deg ____

Remarks: ____

CLIENT NEVADA POWER COMPANY LOCATION REID GARDNER PLOT 12

NUMBER 4 G MACHINERY COOLING TOWER



Date: APRIL 8, 1985

Time: 23.20

Machine: GEARBOX

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks:

Date: APRIL 8, 1985

Time: 23.20

Machine: GEARBOX

Loc: HORIZONTAL

I.P.S.

Mils ____ Deg ____

Remarks:

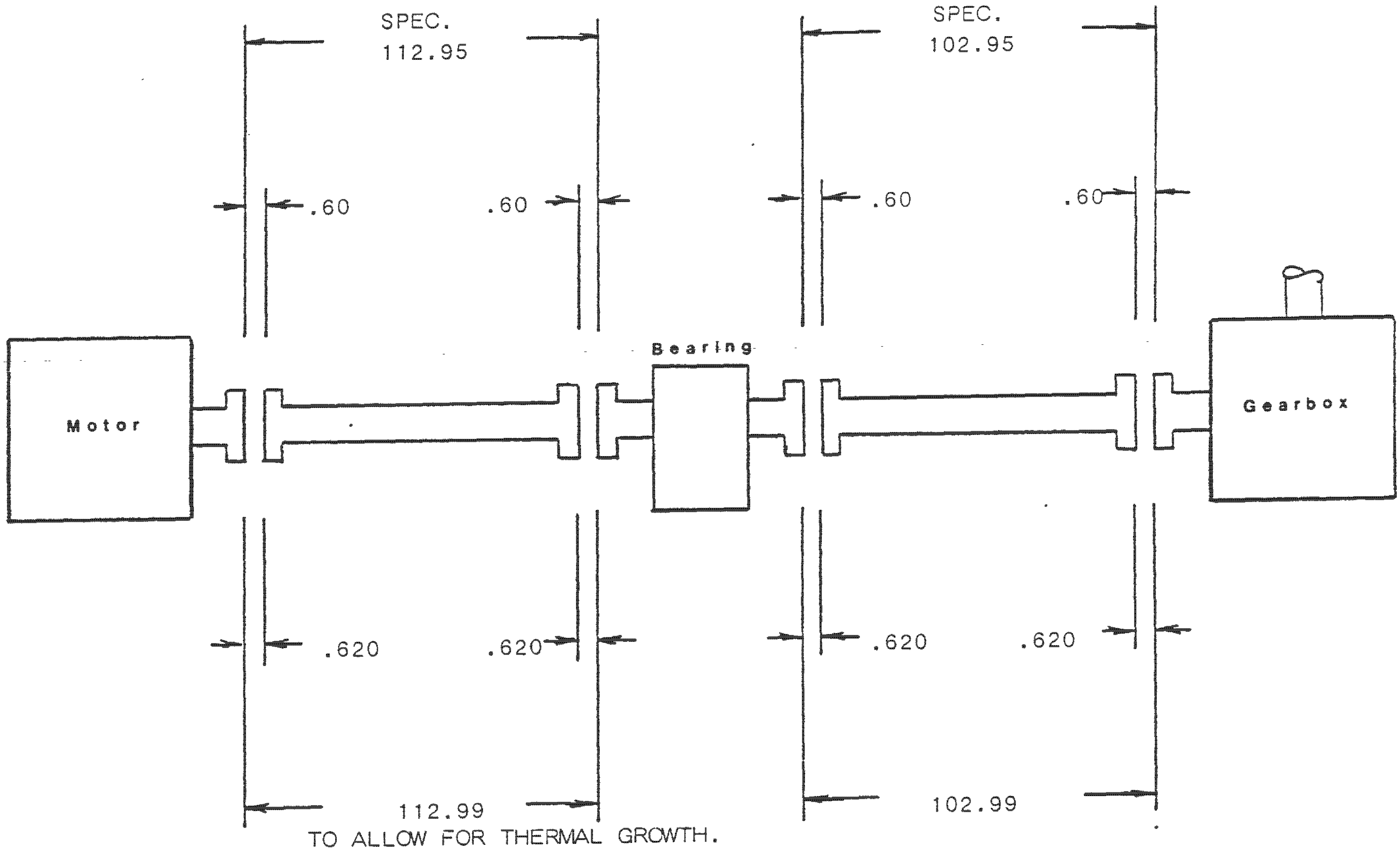
IP12_011497

5.0 COOLING TOWER COUPLING GAPS

The manufactures specification for proper coupling gaps are displayed on page 5-1. We have also calculated the cold desired coupling gap based on a thermal growth of 20 degrees F.

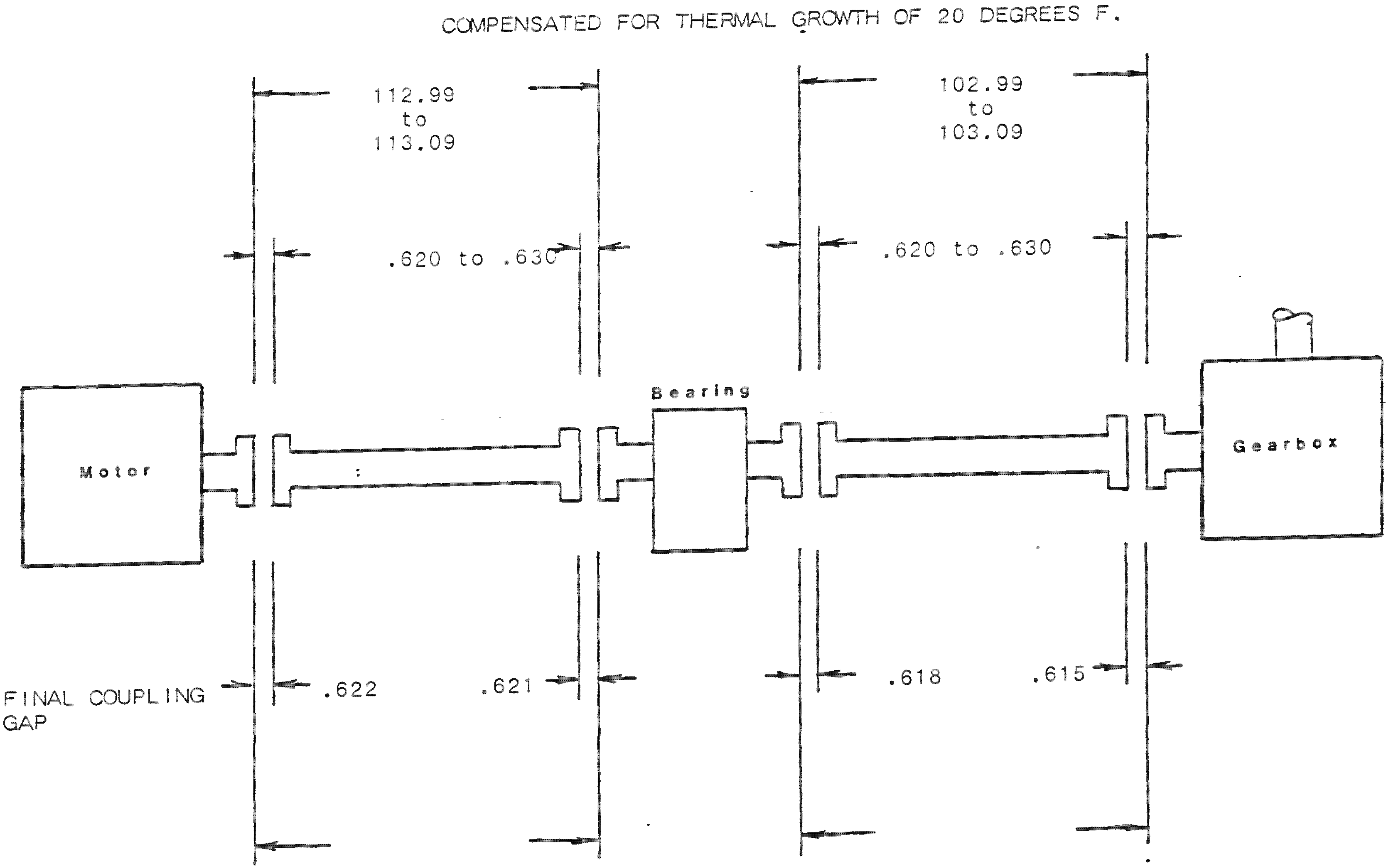
The final cold coupling gaps for Cell "D" are recorded on page 5-2.

The As Found hot coupling gaps for Cell "A" and "G" are recorded on pages 5-3 and 5-4.



COOLING TOWER COUPLING GAP

NEVADA POWER COMPANY



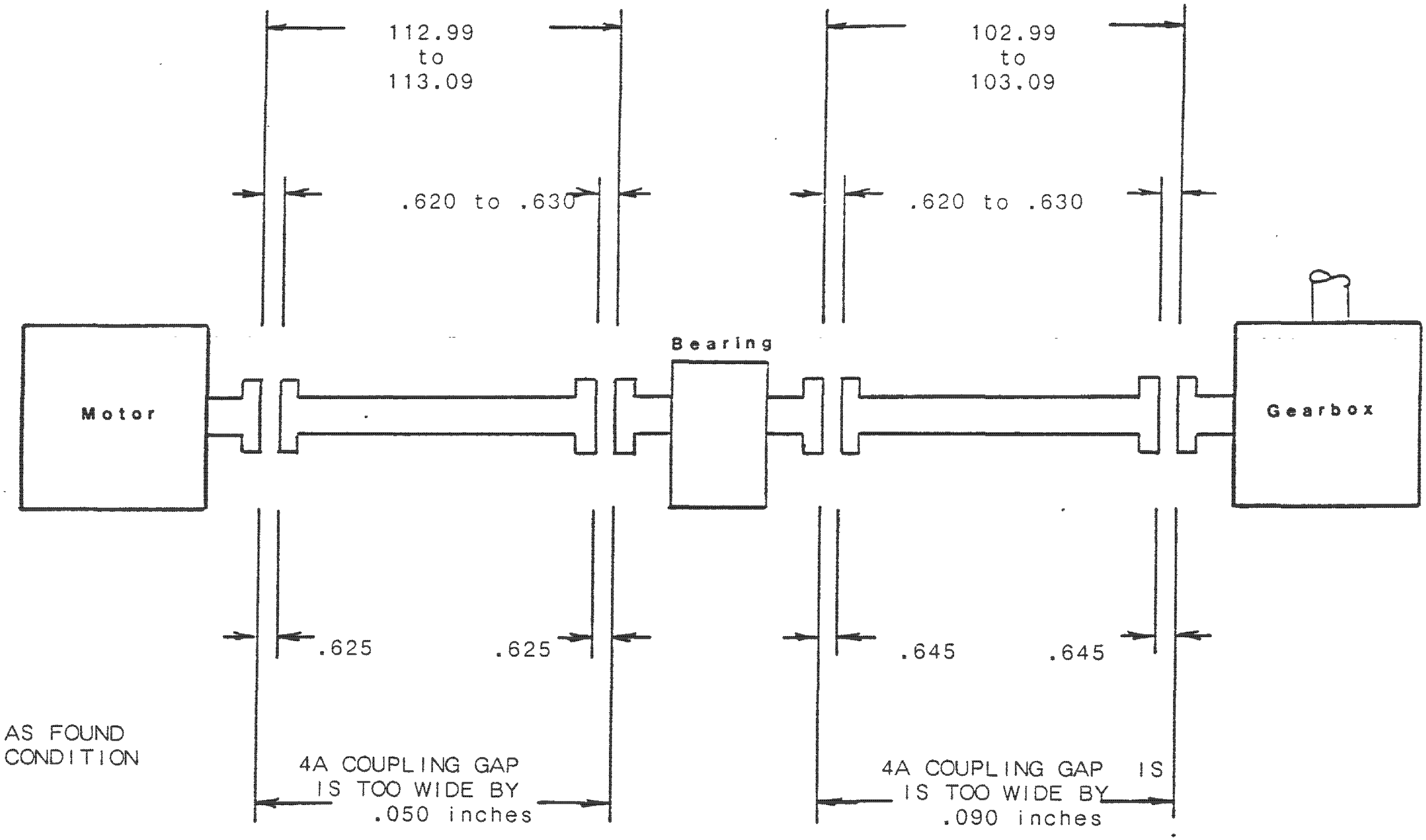
UNIT NO. 4 D

COOLING TOWER COUPLING GAP

APRIL 15, 1985

NEVADA POWER COMPANY

COMPENSATED FOR THERMAL GROWTH OF 20 DEGREES F.

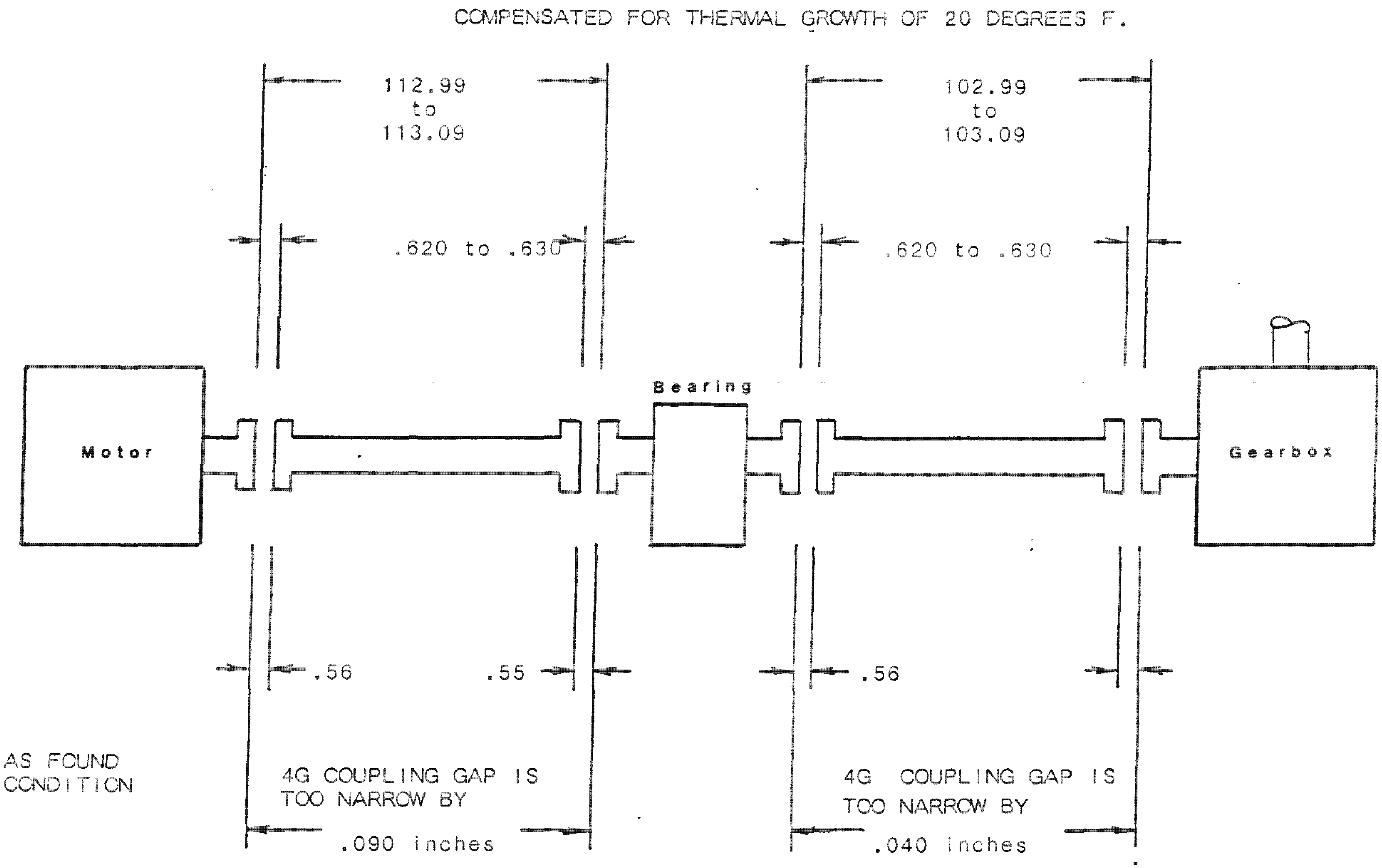


UNIT NO. 4 A

COOLING TOWER COUPLING GAP

APRIL 7, 1985

NEVADA POWER COMPANY



UNIT NO. 4 G

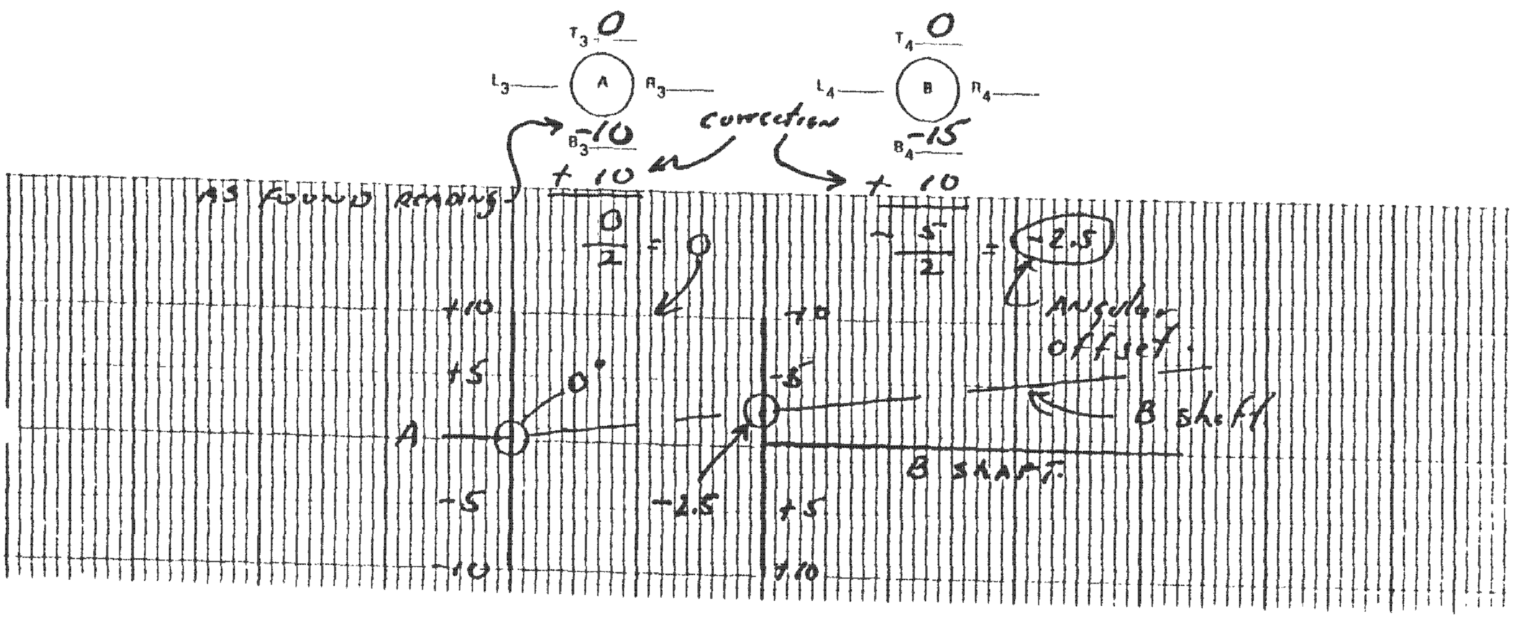
COOLING TOWER COUPLING GAP

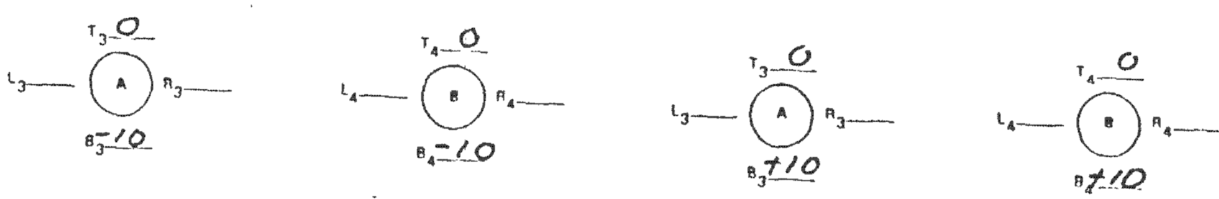
APRIL 7, 1985

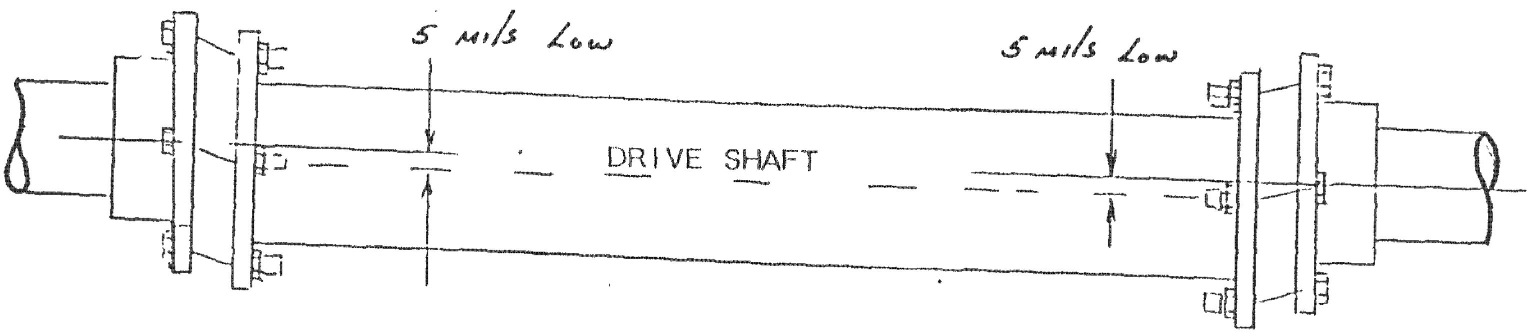
NEVADA POWER COMPANY

6.0 COOLING TOWER ALIGNMENT

Cooling tower drive shafts that have no support bearing have a tendency to sag, due to gravitational forces. The amount of sag will depend on the coupling design and will vary accordingly. When the reverse indicator alignment method is used on this application, the vertical offset will have to be corrected to reflect the true shaft position. The amount of offset can be identified by the negative values on the left coupling and the positive values on the right coupling.
Correction for this offset can be accomplished by canceling the shaft centerline offset and plotting the angular offset.







DESIRED READING | AS FOUND READING | FINAL READING

DESIRED READING

A: T_1 ___ L_1 ___ R_1 ___ B_1 ___

B: T_2 ___ L_2 ___ R_2 ___ B_2 ___

AS FOUND READING

A: T_3 0, L_3 -8, R_3 -11, B_3 -20

+5 sag
-15
+13
-2

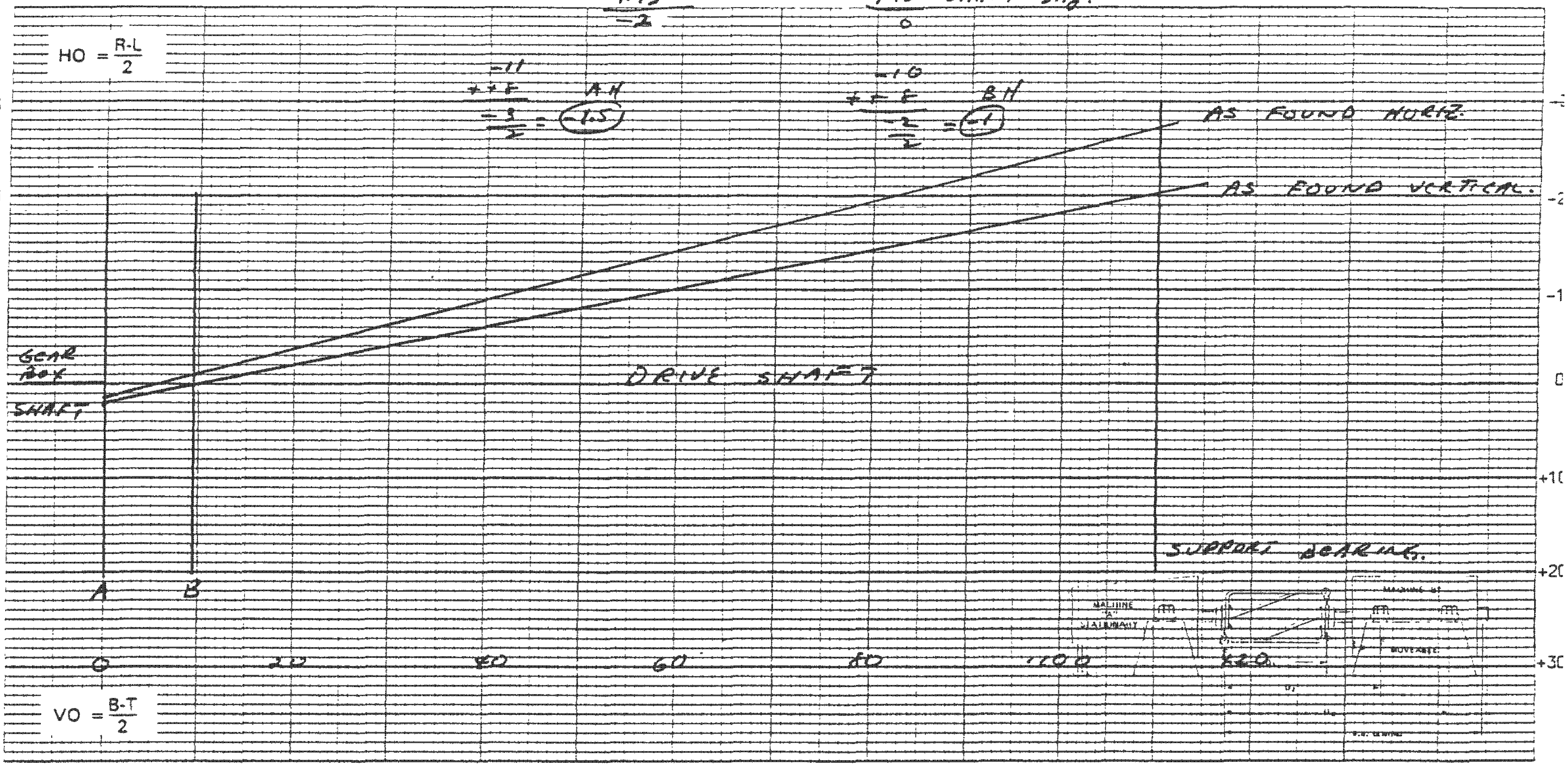
B: T_4 0, L_4 -8, R_4 -10, B_4 -18

+5 sag.
-13
+13 SHAFT SAG.
0

FINAL READING

A: T_3 ___ L_3 ___ R_3 ___ B_3 ___

B: T_4 ___ L_4 ___ R_4 ___ B_4 ___



D1 9.5 D2 110" D3 ________ O.B. BEARING ________ O.B. BEARING TOL. ± ________

MACHINE Unit 4 D Cooling Tower COUPLING RUNOUT A = ________ COUPLING SPAN .622 .621 A.F. ________

MEZCO LOCATION Reid Gardner COUPLING RUNOUT B = ________ PLOT NO. 1

CLIENT Nevada Power Co DATE 4-15-85 @ 17:41 HRS

IP12_011504

DESIRED READING

T_1 ___ L_1 ___ (A) R_1 ___ B_1 ___

T_2 ___ L_2 ___ (B) R_2 ___ B_2 ___

AS FOUND READING

T_3 0 L_3 +42 (A) R_3 -32 B_3 +10

+10
+5
+15 / 2 = +7.5
+7.5 - 7.5 = 0

-32
- +42
-74 / 2 = -37 AH

T_4 6 L_4 +13 (B) R_4 -3 B_4 +10

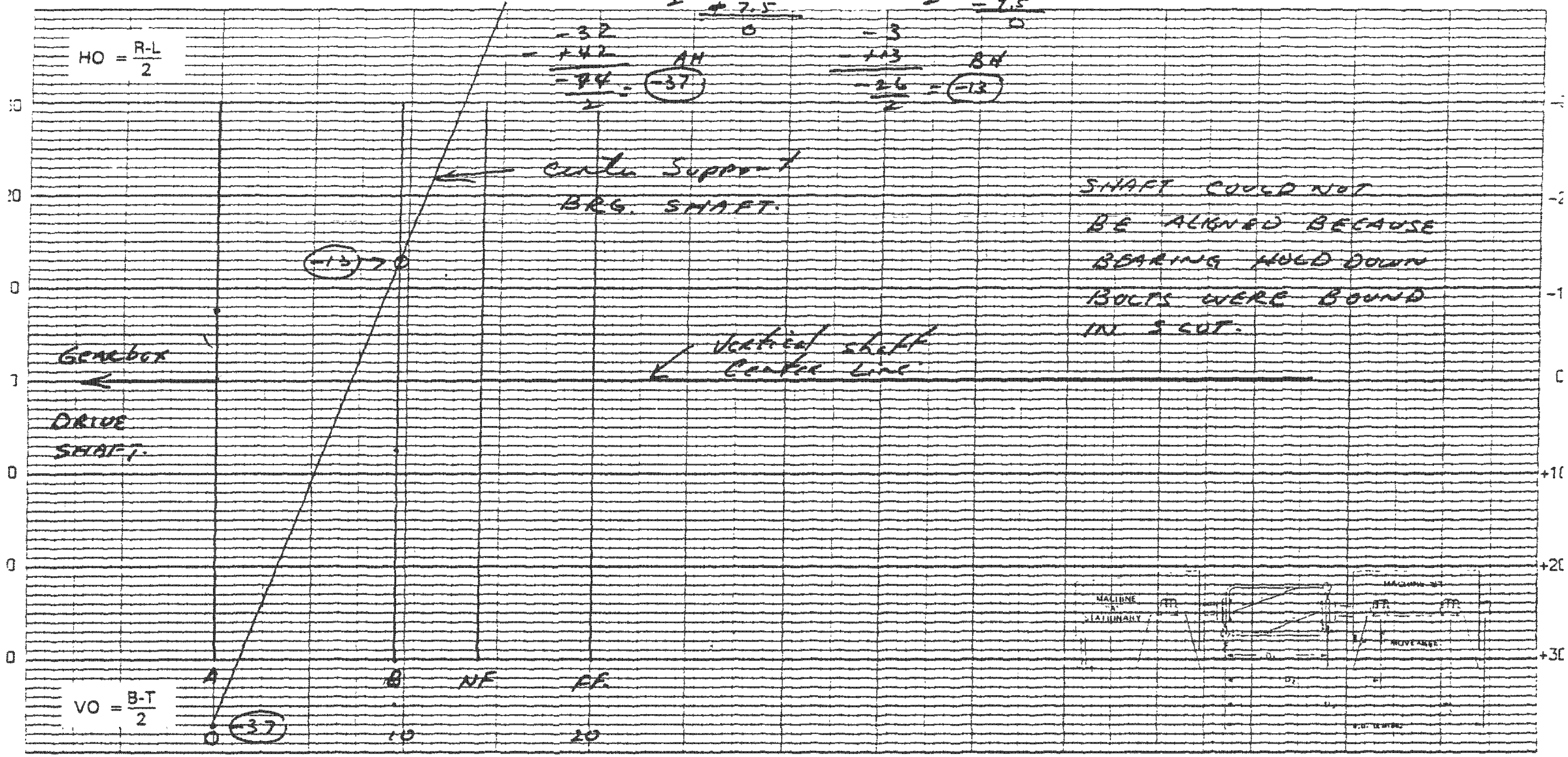
+10
+5
+15 / 2 = +7.5
-7.5 = 0

-3
- +13
-26 / 2 = -13 BH

FINAL READING

T_3 ___ L_3 ___ (A) R_3 ___ B_3 ___

T_4 ___ L_4 ___ (B) R_4 ___ B_4 ___



D1 9.5 D2 14 D3 20 O.B. BEARING ________ O.B. BEARING TOL. ± ________

MACHINE UNIT 4 - D COOLING TOWER. COUPLING RUNOUT A = ________ COUPLING SPAN ________ A.F. ________

MEZCO LOCATION REID GARDNER. COUPLING RUNOUT B = ________ PLOT NO. 2.

CLIENT NEVADA POWER CO DATE 4-15-85 @ 1800 HRS

6-2

IP12_011505

DESIRED READING		AS FOUND READING		FINAL READING	
A: T_1 ___ L_1 ___ R_1 ___ B_1 ___	B: T_2 ___ L_2 ___ R_2 ___ B_2 ___	A: T_3 0, L_3 -9, R_3 -7, B_3 -11	B: T_4 0, L_4 -30, R_4 -46, B_4 -35	A: T_3 0, L_3 -9, R_3 -7, B_3 ___	B: T_4 0, L_4 +4, R_4 +2, B_4 ___

-11
+11
0
+5 SAG
$\frac{+5}{2}$ = +2.5

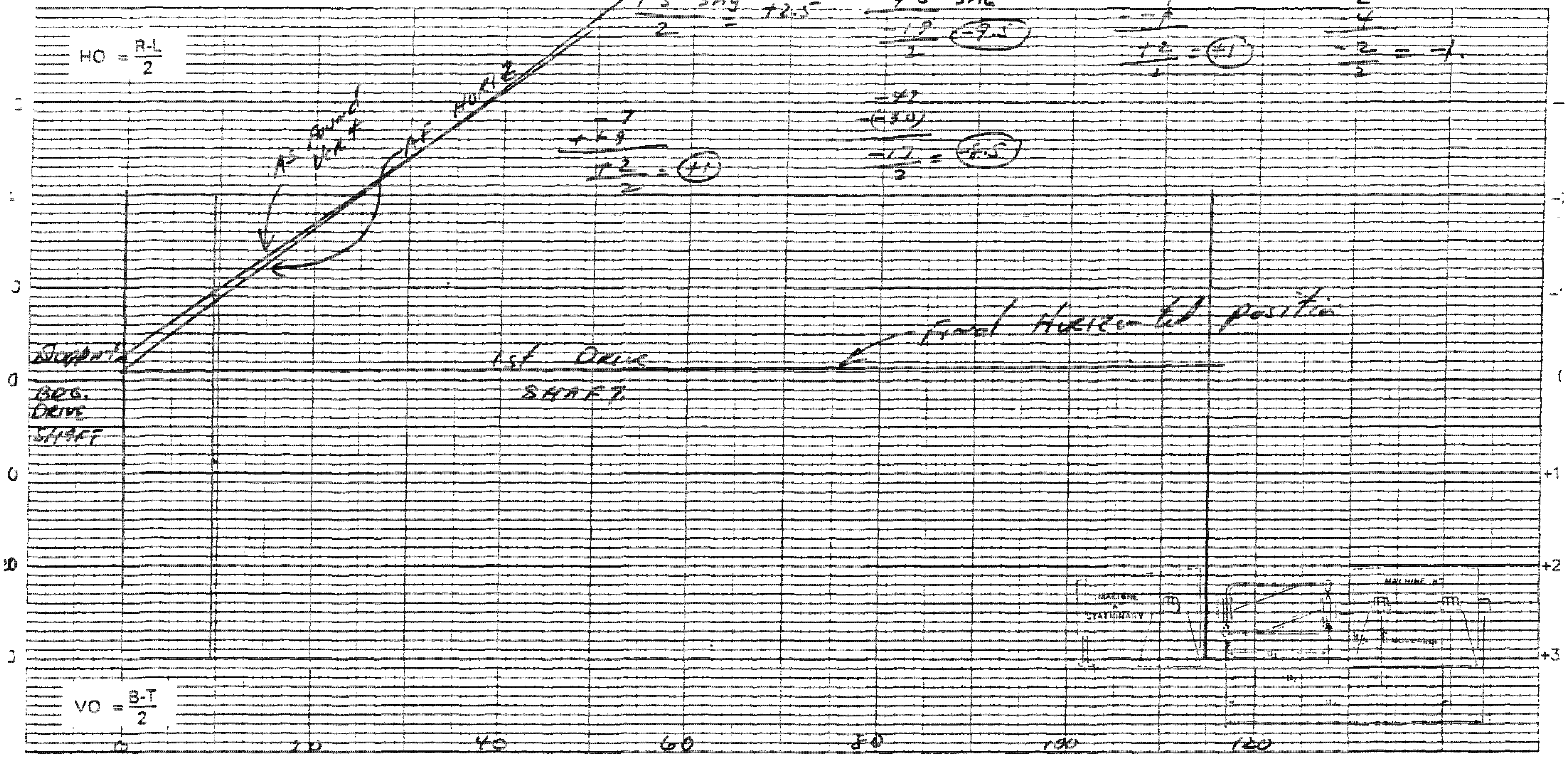
-35
+11
-24
+5 SAG
$\frac{-19}{2}$ = -9.5

-7
-9
$\frac{+2}{2}$ = +1

2
4
$\frac{-2}{2}$ = -1

-7
+-9
$\frac{+2}{2}$ = +1

-47
-(-30)
$\frac{-17}{2}$ = -8.5



D1 9.5 D2 115 D3 ________ O.B. BEARING ________ O.B. BEARING TOL. ± ________

MACHINE Unit 4-D Cooling Tower COUPLING RUNOUT A = ________ COUPLING SPAN ________ A.F. ________

MEZCO

LOCATION Reid Gardner COUPLING RUNOUT B = ________ PLOT NO. 3

CLIENT Nevada Power Co DATE 4-15-85 @ 1830 HRS

6-3

IP12_011506

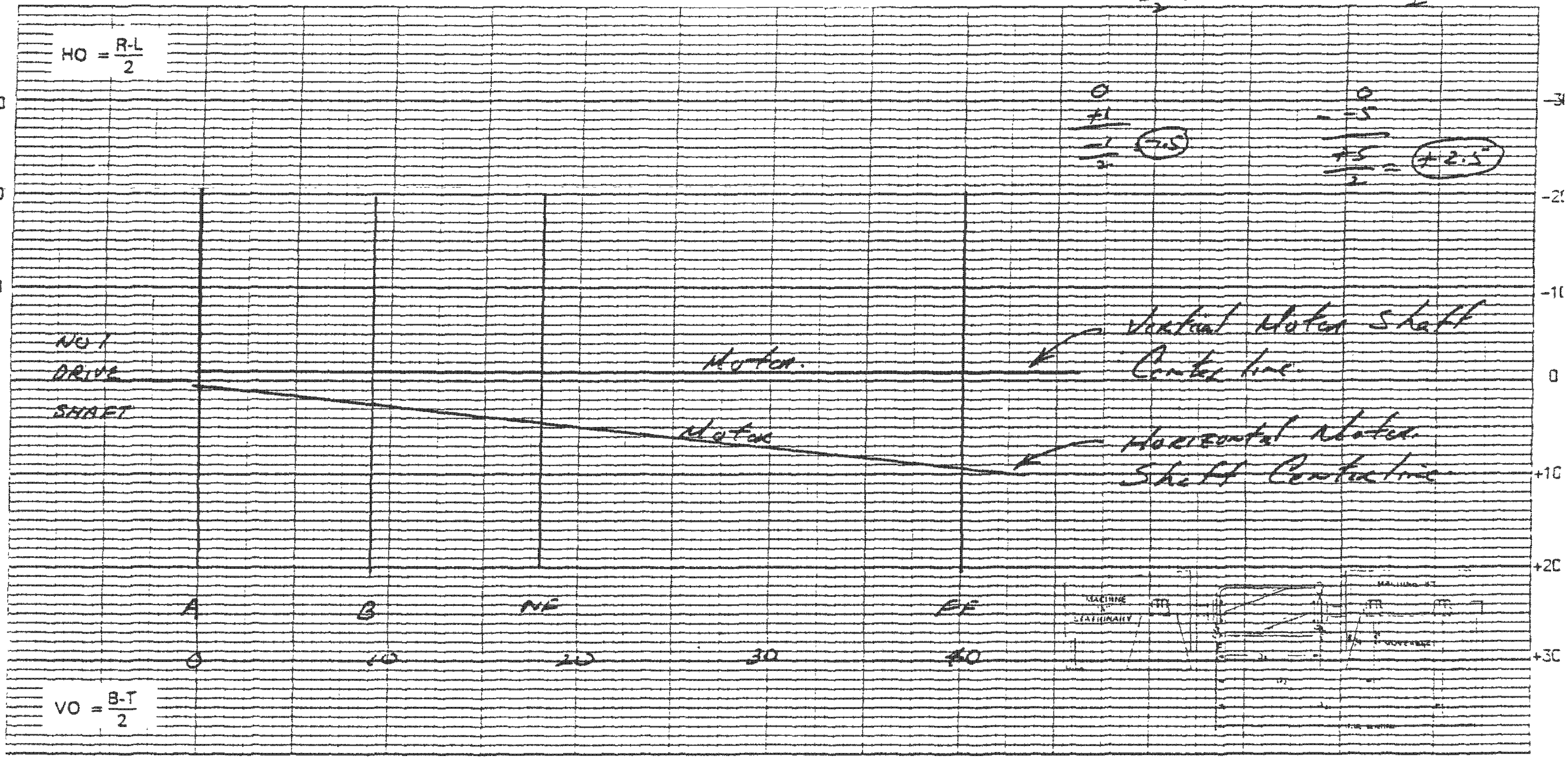
DESIRED READING | **AS FOUND READING** | **FINAL READING**

DESIRED READING:
A: T_1 ___ L_1 ___ R_1 ___ B_1 ___
B: T_2 ___ L_2 ___ R_2 ___ B_2 ___

AS FOUND READING:
A: T_3 ___ L_3 ___ R_3 ___ B_3 ___
B: T_4 ___ L_4 ___ R_4 ___ B_4 ___

FINAL READING:
A: T_3 0, L_3 +1, R_3 0, B_3 −3
+5
+2 / 2 = 1

B: T_4 0, L_4 −5, R_4 0, B_4 −7
+5
−2 / 2 = −1



D1 9 D2 18 D3 40 O.B. BEARING ___ O.B. BEARING TOL. ± ___

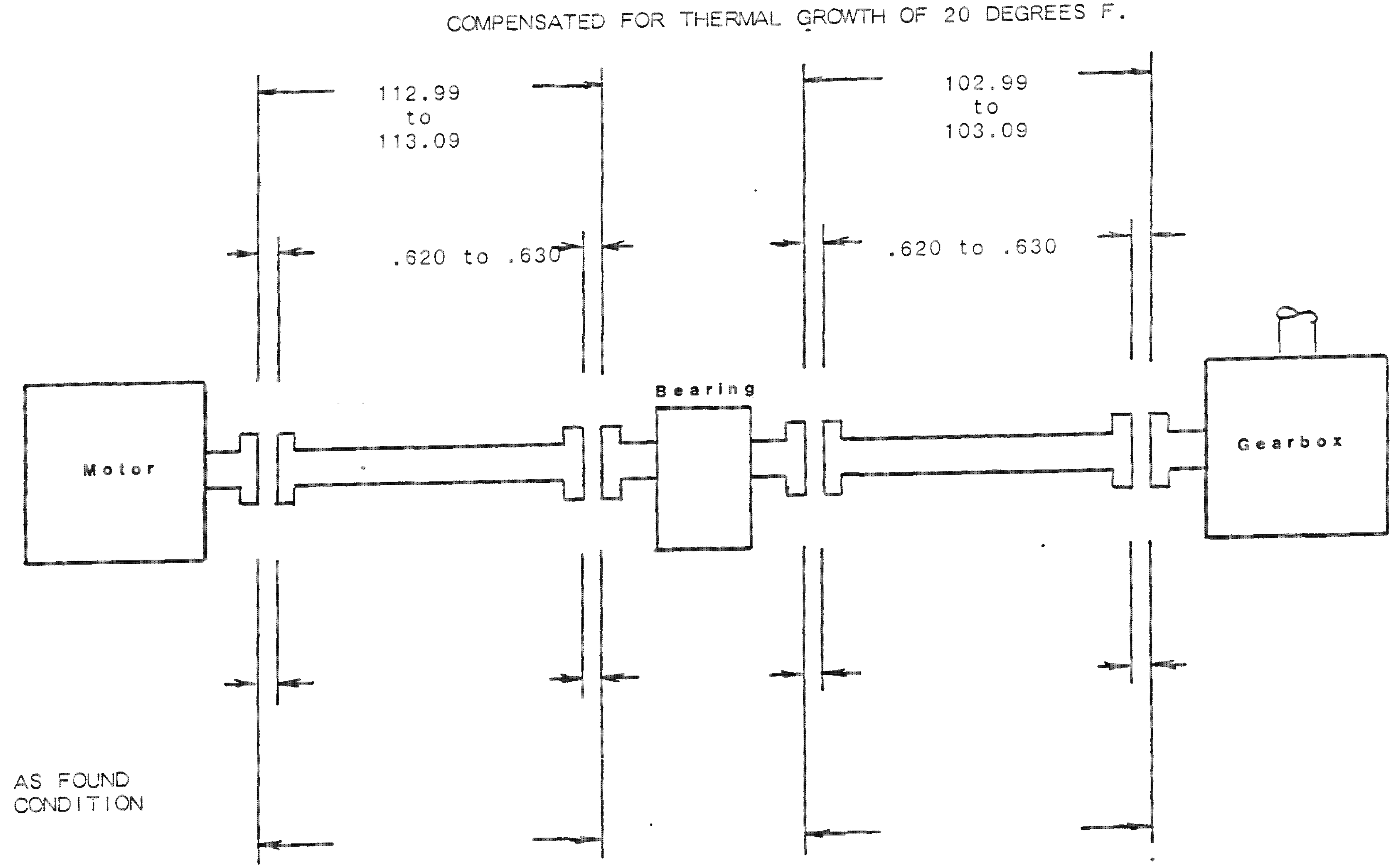
MACHINE Unit No 4 D Cooling tower. COUPLING RUNOUT A = ___ COUPLING SPAN ___ A.F. ___

MEZCO LOCATION Reid Gardner. COUPLING RUNOUT B = ___ PLOT NO. 4

CLIENT [illegible] DATE [illegible] HRS

IP12_011507

APPENDIX



COOLING TOWER COUPLING GAP

NEVADA POWER COMPANY

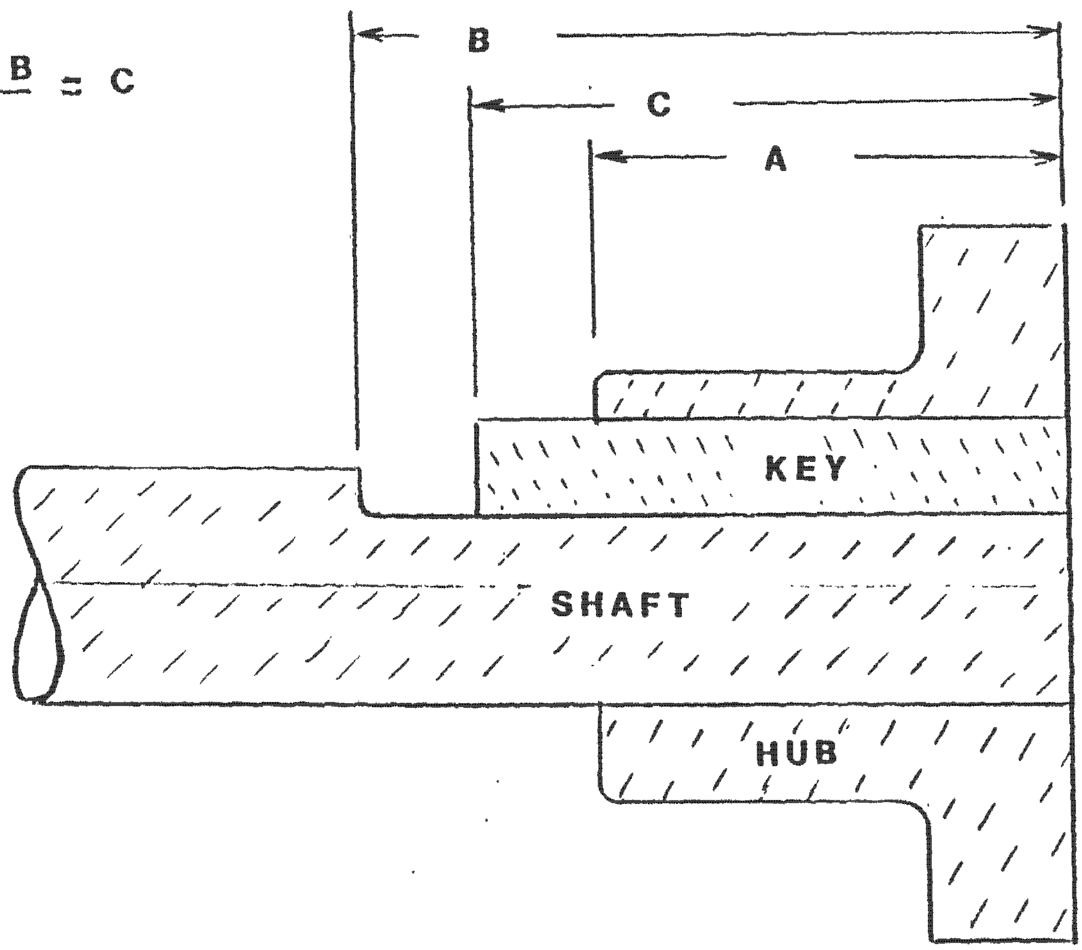
COUPLING KEY

A = COUPLING HUB LENGTH

B = KEY SLOT IN SHAFT

C = KEY LENGTH

$$\frac{A + B}{2} = C$$



MEZCO CORPORATION
7721 Colgate Avenue, Westminster, CA 92683 (714) 894-6017

NEVADA POWER COMPANY

REID GARDNER UNIT NO. 4
COOLING TOWER

FUNDAMENTAL VIBRATION FREQUENCIES

CENTER SUPPORT BEARING

BEARING MANUFACTURE SKF P/N = 6215
NDH P/N = 3216

COMPONENT		CPM	HZ
FUNDAMENTAL TRAIN FREQ.	(FTF)	735	12.2
BALL PASS FREQ. INNER RACE	(BPFI)	10,441	174.0
BALL PASS FREQ. OUTTER RACE	(BPFO)	7,358	122.0
BALL SPIN FREQ.	(BSF)	4,984	83.0

GEARBOX GEAR MESH

COMPONENT	RPM	X	NO. OF TEETH	=	MESH FREQ.
G.B. INPUT SHAFT	1780		16	=	28,480
G.B. OUTPUT SHAFT	94.6		109		10,311